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Housing Market Bust and Farmland Values: Identifying the Changing Influence of Proximity to Urban Centers

Wendong Zhang
Iowa State University, wdzhang@iastate.edu

Cynthia J. Nickerson
United States Department of Agriculture

Abstract

This article estimates the impact of the 2007–2008 residential housing market bust on farmland values, using parcel-level farmland sales data from 2001–2010 for a 50-county region under urbanization pressure in western Ohio. Hedonic model estimates reveal that farmland was not immune to the residential housing bust; the portion of farmland value attributable to proximity to urban areas was almost cut in half shortly after the bust in 2009–2010. Nonetheless, total farmland prices remained relatively stable in the 2000s, likely due to increased demand for agricultural commodities. Our results are robust to different assumptions about the structure of the unobserved spatial correlation.

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ABSTRACT. *This article estimates the impact of the 2007–2008 residential housing market bust on farmland values, using parcel-level farmland sales data from 2001–2010 for a 50-county region under urbanization pressure in western Ohio. Hedonic model estimates reveal that farmland was not immune to the residential housing bust; the portion of farmland value attributable to proximity to urban areas was almost cut in half shortly after the bust in 2009–2010. Nonetheless, total farmland prices remained relatively stable in the 2000s, likely due to increased demand for agricultural commodities. Our results are robust to different assumptions about the structure of the unobserved spatial correlation.* (JEL Q15, R14)

I. INTRODUCTION

The recent residential housing market bust and subsequent economic recession led to a dramatic decline in urban land and housing values across the United States. According to Standard & Poor's Case-Shiller repeat sales price index, residential property values in major metropolitan areas declined by about 40% between 2007 and the end of 2008. Although farmland near urban areas derives some of its value from factors affecting urban land values, a corresponding dip was not evident in farmland prices. Survey data reveal that in many states, farm real estate values modestly increased rather than decreased over 2007–2009 (Nickerson et al. 2012). These trends raise a question about the relationship between urban and farmland markets: what was the magnitude, if any, of the drag imposed by the urban residential housing market downturn on surrounding farmland values? It is possible that favorable changes in factors that positively influence farmland values—including historically low interest rates that increase the attractiveness of farmland as an investment, and increasing demands for commodities (e.g., Schnitkey and Sherrick 2011)—may have masked declines attributable to the residential housing market bust. Understanding how farmland values respond to fluctuations in urban land markets is of perennial policy interest. About one-fourth of farmland is subject to urban influences, and because farmland values represent over 80% of the value of farm sector assets, changes in farmland values can affect the health of the farm sector and farm household wellbeing (Nickerson et al. 2012).

Farmland in close proximity to urban areas typically sells for a premium relative to farmland farther away from urban areas, as demand for developable land induces developers to bid above the agricultural production value of land closest to urban areas (Capozza and Helsley 1989). Many empirical studies have shown that in urbanizing areas the demand for developable land for residential or commercial uses is the most significant nonfarm factor affecting farmland values (e.g., Livanis et al. 2006; Hardie, Narayan, and Gardner 2001; Shi, Phipps and Colyer 1997; Cavailhès and Wavresky 2003; Plantinga, Lubowski, and Stavins 2002; Ma and Swinton 2012). Most of these studies use aggregate county-level data, which generate a very coarse representation of the spatial extent and magnitude of such urban influence on farmland values. Studies by Guiling, Brorsen, and Doye (2009) and Tsoodle, Featherstone, and Golden (2007)

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The authors are, respectively, assistant professor, Department of Economics, Iowa State University, Ames; and senior economist, U.S. Department of Agriculture, Economic Research Service, Washington, D.C.

are two more recent ones that use parcel-specific data to measure urban influences on farmland values. Guiling, Brorsen, and Doye (2009) used a farm parcel's distance to the closest city as a proxy for future development pressure, to estimate the size of the effect of urban proximity on farmland values in Oklahoma. Tsoodle, Featherstone, and Golden (2007) used distances to multiple city centers to proxy the impacts of urban pressure on Kansas farmland values from 1996 to 2004. Studies of the impacts on land markets of the housing boom and bust have been limited to residential land and structure values and have not quantified the impact on surrounding farmland that could be developed (Ihlanfeldt and Mayock 2014; Kuminoff and Pope 2013; Cohen, Coughlin, and Lopez 2012).

The aim of this article is to test for a structural change in farmland values due to the 2007–2008 urban housing market bust. We hypothesize that the urban housing market bust imposed significant downward pressure on urban demands for developable land and, hence, the urban premium that accrues to farmland near urban areas. This article uses parcel-level, arm's-length agricultural land sales data from 2001 to 2010, a period that encompasses the housing market bust, for a 50-county region of western Ohio, almost all of which is subject to some degree of urban influence. This unique dataset allows us to parse the data into preboom (2000–2006) and postbust (2009–2010) time periods, and to develop a measure of "urban premium" that quantifies for each farmland parcel the total dollar value arising from proximity to multiple urban areas relative to a hypothetical rural parcel. We use this urban premium measure to investigate the structural change in the effects of urban proximity on surrounding farmland values due to the recent housing market bust.

A common challenge in land value studies arises from unobserved characteristics that are spatially correlated, which can lead to inefficient coefficient estimates, or even bias the coefficient estimates of our proximity measures if the two are correlated. Because the structure and sources of this correlation are inherently unknown to the researcher, no one model can be known with certainty to correctly control for this unobserved component. Instead, maintained assumptions are required for identification, and the model results are dependent on the validity of these maintained assumptions. In such cases, results that are robust to multiple model specifications provide convincing evidence of a structural change in the effect of urban proximity on farmland values. We use two main model specifications—a spatial fixed-effects model delineated by census tracts, and a spatial error model with a nearest-neighbor spatial weights matrix—and a variety of alternative specifications of these two models to test the stableness of our results. Both types of models control for the effects of unobserved characteristics but make different assumptions about the structure of the unobserved correlation and have different interpretations of the estimates.

The two main models both provide evidence that the portion of farmland values attributable to the urban premium declined by about 50% due to the recent housing market bust. On average, the urban premium for parcels under urban influence relative to a hypothetical parcel not subject to urban influence, declined from about 40% of per-acre farmland prices to roughly 20% after the housing market bust. The decline in urban premium due to the housing market bust was greater for parcels closest to cities. In addition, the results illustrate the importance of incorporating influences from multiple urban centers, in regions like western Ohio. Results from the spatial fixed-effects and spatial error models reveal that the average urban premium would be underestimated by 17% to 34% before 2007 if measures accounting for multiple urban centers are omitted. This suggests multiple urban centers represent a significant portion of the urban premium, at least in periods of strong housing market growth. We also note that because census tract fixed effects may absorb part of the effect of proximity to urban areas, our estimates of the urban premium are possibly underestimated in this model. However, the estimates from the spatial error model are only slightly higher, suggesting that any underestimation is not large.

Overall, this study makes at least two contributions to the farmland valuation literature. First, to our knowledge, this paper offers the first analysis of the magnitude of the structural break in the effect of urban influence on surrounding farmland values due to the recent housing market bust—yielding new insights into the impacts of changes in competing land markets on farmland values. In addition, this paper develops a parcel-level measure of urban premium that explicitly accounts for the influences of multiple urban centers and shows that not accounting for the effects of multiple urban centers can result in a substantial undervaluation of the urban premium, at least in areas that are subject to significant urban influences, such as Ohio.

II. CONCEPTUAL FRAMEWORK

Among the most influential theories that help explain the value of land is Ricardo's (1996/1817) economic theory of rent. Ricardo's key insight was that land that differs in quality and is limited in supply generates rents that arise from the productive differences in land quality or in differences in location. The valuation of farmland subject to urban influence dates back to a model developed by Von Thünen, in 1826 (1966), which posits that rent differentials for farmland also arise both from the value of commodities produced and the distance from central markets. In this model the Ricardian rent is a decreasing function of the distance to the urban center, and land closer to the urban center earns higher rents because of reduced transportation costs. Farmland value is comprised of the net present value of economic returns to land. The model is written as

$$V_{it} = E_t \sum_{s=t}^{\infty} \frac{R_{is}}{(1+\delta)^{s-t}}. \qquad [1]$$

In this formulation, the value of agricultural land parcel i in year t, V_{it}, is defined as the expected annual returns to farmland R discounted at rate δ. In many regions, farmland can earn returns not just from agricultural production and government payments, but also from nonfarm sources such as hunting and fishing. Principal among the nonfarm sources of returns for farmland in close proximity to urban areas is the expected future rent increases arising from expected returns from future development for residential or commercial uses. Capozza and Helsley's (1989) seminal work laid the theoretical foundation for this literature and showed how the value of expected future rent increases could be quite large, especially near rapidly growing cities.

The study region—western Ohio—is fairly homogenous in climatic conditions and opportunities for fishing or hunting opportunities, and hence little variation in generating recreational income is expected among the parcels. This area faces significant development pressure, however, so we focus on returns arising from the option value of future land conversion from agricultural use to urban uses. Following Capozza and Helsley (1989), the value of an agricultural parcel i in year t under urban influence can be defined as

$$V_{it} = \sum_{s=t}^{t^*} \frac{R_{\mathrm{A}}(\mathbf{A}_{is})}{(1+\delta)^{s-t}} + \sum_{s=t^*}^{\infty} \frac{R_{\mathrm{U}}(\mathbf{U}_{is})}{(1+\delta)^{s-t}}, \; t \in [0,\, t^*], \qquad [2]$$

where t^* is the optimal timing of land use conversion from agricultural use to residential or commercial uses, R_{A} is the agricultural land rent, and R_{U} is the urban land rent net of conversion costs. The first term represents the present value of agricultural rents up to t^*, which depends on the parcel-specific variables affecting agricultural productivity, $\mathbf{A}_{is}$, such as soil quality, slope of the parcel, and proximity to agricultural market channels such as ethanol plants and grain elevators. The second term captures the present value of returns to urban development from the optimal conversion time onward, which depends on the location-specific urban influences variables, $\mathbf{U}_{is}$, such as proximity to nearby cities, surrounding urban population, size of nearby multiple urban centers, and access to highway ramps and railway stations.[1] The recent hous-

[1] The increased access to customers could also influence farmland values by increasing expected agricultural returns. However this effect may be most relevant when there are many dairy, fruit, and vegetable farms, which is not the case for our study region.

ing market bust may delay the optimal timing of conversion to an urban land use and greatly diminish the urban option conversion value of agricultural land relative to the preceding period of high housing demand. As a result, a declining significance of the urban influence variables, $\mathbf{U}_{is}$, in shaping surrounding farmland values is expected between the two periods.

III. ECONOMETRIC PROCEDURES

The Hedonic Price Method

Hedonic models are a revealed preference method based on the notion that the price of a good or parcel in the marketplace is a function of its attributes and characteristics. With Rosen's (1974) seminal work as a backdrop, the hedonic price method has become the workhorse model in studies of real estate values (e.g., Palmquist 1989), and the determinants of farmland values. Numerous applications of hedonic models applied to farmland markets have examined the marginal value of both farm and nonfarm characteristics of farmland, including soil erodibility (e.g., Palmquist and Danielson 1989), urban proximity (e.g., Shi, Phipps, and Colyer 1997), wildlife recreational opportunities (e.g., Henderson and Moore 2006), zoning (e.g., Chicoine 1981), and farmland protection easements (e.g., Nickerson and Lynch 2001). The farmland returns R_{it} in equation [2] can be approximated by a linear combination of parcel attributes and location characteristics. Hedonic models are commonly specified in log-linear form,[2] which is defined as

$$\log(V_{it}) = \beta_0 + \beta_{\mathrm{A}}{}'\mathbf{A}_{it} + \beta_{\mathrm{U}}{}'\mathbf{U}_{it} + \tau_t + \varepsilon_{it}, \qquad [3]$$

where τ_t is time fixed effects, which captures the temporal variations in returns and discount factor, the β's are coefficients to be estimated, and ε_{it} is a normally distributed error term. Agricultural land values V_{it} are approximated by the nominal sale prices per acre of the agricultural land without structures.

In this hedonic setting, agricultural land is regarded as a differentiated product with a bundle of agricultural quality and location characteristics, and each characteristic is valued by its implicit price.

Addressing the Potential for Unobserved Spatial Correlation

Despite its popularity, the hedonic pricing method suffers from a number of well-known econometric problems. Most prominent among them in land value models is the potential for spatial autocorrelation arising from unobserved characteristics. Our particular concern is unobserved variables that may be systematically correlated with distances to urban areas, which could lead to biased estimates of the implicit prices of the key observed proximity attributes we use to construct the urban premium measure (Irwin 2002).[3] For example, distance to, type and size of industrial facilities, rural employment centers, or input suppliers may all influence farmland prices and also may be correlated with distance to urban areas even if they are not co-located with an urban area.

The true structure and sources of this spatial correlation are inherently unknown to the researchers, and there is ongoing debate in the literature about how to best deal with this potential problem (e.g., Kuminoff, Parameter, and Pope 2010; Anselin and Arribas-Bel 2013). A spatial error model explicitly models the spatial dependence among error terms and, if correctly specified, controls for the observed spatial correlation among neighboring farmland parcels (e.g., Anselin and Arribas-Bel 2013). However, this approach has been criticized (e.g., Gibbons and Overman 2012;

[2] We choose a log-linear functional form rather than the Box-Cox transformation of both dependent and independent variables because our interaction terms of urban influence have many zeros: Box-Cox transformation requires positive values. A robustness check using a Box-Cox transformation of the dependent variable (sale prices of farmland parcels) only yields a Box-Cox transformation parameter of 0.27, which is close to 0 as the parameter implied by log-linear functional form; also, the Box-Cox regression yields qualitatively similar results. We also add one robustness check using log-log specification, and the results shown in Appendix Table A1 column (d) yield qualitatively similar conclusions.

[3] If unobserved characteristics are not correlated with distance, spatially correlated error terms will result only in inefficient rather than biased parameter estimates (Dubin 1988).

McMillen 2010) since it makes strong, a priori assumptions about the true structure of the error terms, and the form of the spatial weights matrix is often exogenously imposed. As a practical alternative that makes fewer assumptions about the error structure, many researchers have embraced the spatial fixed-effects model (Kuminoff, Parameter, and Pope 2010). This model incorporates fixed effects that correspond to the scale of the unobserved variables that give rise to spatial correlation, such as census tracts. However, despite the advantage of requiring fewer assumptions, a spatial fixed-effects approach has several limitations in the context of this paper. The fixed effects serve as another measure of location, so the model potentially yields only a partial estimate of the total urban effect by capturing part of the unobserved characteristics that are attributable to urban influence. In addition, it does not control for unobserved spatial correlation that varies within census tracts. It could also introduce spurious spatial error when the unobserved characteristics do not correspond well to the census tract administrative boundaries (Anselin and Arribas-Bel 2013). Given this ongoing debate and the unknown nature of the true error structure, we use both the spatial fixed-effects and spatial error models as our main model specifications, and we examine the extent to which our results are robust across these specifications.

In the first model, we incorporate into the hedonic model the spatial fixed effects delineated at census tract levels and denoted as θ_j (where the subscript j represents the census tract):

$$\log(V_{it}) = \beta_0 + \beta_A{}'\mathbf{A}_{it} + \beta_U{}'\mathbf{U}_{it} + \tau_t + \theta_j + \varepsilon_{it}. \qquad [4]$$

In contrast, a spatial error model addresses the spatial dependence by incorporating a spatial weights matrix in modeling the error term:

$$\log(V_{it}) = \beta_0 + \beta_A{}'\mathbf{A}_{it} + \beta_U{}'\mathbf{U}_{it} + \tau_t + \varepsilon_{it}, \quad \text{with } \varepsilon = \rho\mathbf{W}\varepsilon + u, \qquad [5]$$

where $\mathbf{W}$ is an $n \times n$ spatial weights matrix, the scalar ρ is the spatial autocorrelation coefficient, and u is a spatially uncorrelated error term. In this paper, we use a row-standardized k-nearest-neighbor spatial weights matrix, a common formulation that assumes spatial dependence decays with distance.

Construction of Urban Premium

To quantify the structural break in the effect of urban influences on surrounding farmland values induced by the housing market bust, we develop a parcel-level measure of an "urban premium." This metric quantifies for each parcel, relative to a hypothetical agricultural land parcel under no urban influence, the total dollar value resulting from being located closer to urban areas. This urban premium measure consists of four distinct parts: the value derived from (1) being closer to the nearest city with at least 40,000 people[4] than the reference parcel, (2) proximity to the second-nearest city as measured by the incremental distance,[5] (3) the surrounding urban population within 25 miles of the parcel centroid, and (4) the total weighted population of the three nearest cities captured in a gravity population index. The latter three parts represent the additional value derived from proximity to multiple urban centers. With these measures, we are able to quantify the difference in the urban premium before and after the housing market bust. To construct this metric for the spatial fixed-effects and spatial error models, the coefficients in the following equations [6a] and [6b] are used, respectively:

$$\log(V_{it}) = \beta_0 + \beta_A{}'\mathbf{A}_{it} + \beta_{U\_boom}{}'\mathbf{U}_{it} + \beta_{U\_bust}{}'\mathbf{U}_{it} {}^* D_{t\_bust} + \tau_t + \theta_j + \varepsilon_{it}, \qquad [6a]$$

[4] In this paper, we define cities as those with at least 40,000 people, and this threshold is used throughout the paper for distance calculations unless noted otherwise. While the threshold of 50,000 people is used by the U.S. Census Bureau to define urbanized areas, we choose the 40,000 people because some core cities in Ohio Metropolitan Statistical Areas such as Lima have fewer than 50,000 people. The results are similar when a 50,000 threshold is used.

[5] The incremental distance to the second-nearest city is defined as the difference between the distance from the second-nearest city center and the distance from the nearest city center. For example, a parcel located 10 miles away from the nearest city center and 30 miles away from the second-nearest city center will have an incremental distance to the second-nearest city of 20 miles.

$$\log(V_{it}) = \beta_0 + \beta_A{'}\mathbf{A}_{it} + \beta_{U\_boom}{'}\mathbf{U}_{it} + \beta_{U\_bust}{'}\mathbf{U}_{it} {*} D_{t\_bust} + \tau_t + \varepsilon_{it}, \quad [6b]$$

where in both cases D_{t_bust} is a binary time dummy indicating that the parcel is sold after the housing market bust. Our main specification uses 2001 to 2006 as the pre (boom) period, and 2009 to 2010 as the post (bust) period. The pre and post periods were determined based on changes in the residential housing price indexes in the Cleveland and Cincinnati metropolitan areas. These indexes exhibited rapid declines through the end of 2008, and a relative leveling off in 2009 and 2010 (Lincoln Institute of Land Policy 2012). The years 2007 and 2008 are treated as a transition period, and thus parcels sold in these years are not included in the regression.

The parcel-level urban premium is calculated as the difference between the predicted prices using actual distance and population variables $\mathbf{U}_{it}$ for each parcel i and the predicted prices for the reference parcel under no urban influence. We use semiparametric regressions to determine the thresholds beyond which the positive coefficients of urban influence variables become insignificant,[6] and use these thresholds as the distance for the reference parcel with no urban influence. Specifically, the distance and population variables for the reference rural parcel $\bar{\mathbf{U}}$ are 60 miles for the *distance to nearest city*, 40 miles for the *incremental distance to the second-nearest city*, and zero for surrounding urban population and gravity index. For all parcels, the values defining the reference rural parcel are the same, and thus the elements of $\bar{\mathbf{U}}$ do not vary by parcel.

Mathematically, for each parcel using either the spatial error or fixed-effects approach, the urban premium is calculated as the difference between the predicted prices $\exp(\widehat{\log(P_{it}(\mathbf{U}_{it}))} + \widehat{\sigma_\epsilon^2}/2)$ using actual urban influence variables $\mathbf{U}_{it}$, and the predicted prices $\exp(\overline{\log(P_{it}(\bar{\mathbf{U}}))} + \widehat{\sigma_\epsilon^2}/2)$ if the urban influence variables for parcel i are replaced by that for the rural parcel $\bar{\mathbf{U}}$. That is, for the spatial error model, $\widehat{\beta_0}$, $\widehat{\beta_A}$, $\widehat{\beta_{U\_boom}}$, $\widehat{\beta_{U\_bust}}$, $\widehat{\tau_t}$, and $\widehat{\sigma_\epsilon^2}$ are the corresponding regression coefficients and the mean squared error (MSE) from equation [6b], and the urban premium is calculated as follows:

$$\widehat{\log(P_{it})} = \widehat{\beta_0} + \widehat{\beta_A}{'}\mathbf{A}_{it} + \widehat{\beta_{U\_boom}}{'}\mathbf{U}_{it} + \widehat{\beta_{U\_bust}}{'}\mathbf{U}_{it} {*} D_{U\_bust} + \widehat{\tau_t}, \quad [7a]$$

$$\overline{\log(P_{it})} = \widehat{\beta_0} + \widehat{\beta_A}{'}\mathbf{A}_{it} + \widehat{\beta_{U\_boom}}{'}\bar{\mathbf{U}} + \widehat{\beta_{U\_bust}}{'}\bar{\mathbf{U}} {*} D_{U\_bust} + \widehat{\tau_t}, \quad [7b]$$

$$\text{Urban premium} = \exp(\widehat{\log(P_{it}(\mathbf{U}_{it}))} + \widehat{\sigma_\epsilon^2}/2) - \exp(\overline{\log(P_{it}(\bar{\mathbf{U}}))} + \widehat{\sigma_\epsilon^2}/2). \quad [8]$$

To calculate the urban premium using the spatial fixed-effects model estimates, the regression coefficients and MSE from equation [6a] are used and $\widehat{\theta_j}$ is included in equation [7].

IV. DATA

Western Ohio hosts the vast majority of the state's agricultural land and provides an excellent laboratory to study structural change in the determinants of farmland values precipitated by the residential housing bust. Ohio's metropolitan areas were hit hard in the housing market bust and accompanying recession, as evidenced by the sharp decline in residential housing prices in its metropolitan areas in 2007 and 2008 (Lincoln Institute of Land Policy 2012). To analyze the impact of the housing market bust on farmland values, we used data on 21,342 agricultural land sales that occurred over 2001–2010 in 50 western Ohio

[6] The semiparametric regressions are estimated using the semip() function from the McSpatial package in R (*McSpatial: Nonparametric Spatial Data Analysis, R Package Version 2.0,* available at cran.r-project.org), and the model specification is following equation [4] with county fixed effects, with either distance to the nearest city center or the incremental distance to the second-nearest city center estimated nonparametrically using locally weighted regressions. A robustness check using 50 miles and 30 miles for the thresholds of the distance to the nearest city center and incremental distance to the second-nearest city center, respectively, yield qualitatively similar results regarding the parcel-level urban premium.

counties. The data were obtained from county assessors' offices and from a private data vendor.

The sample was further screened to eliminate 4,583 farmland parcels under no or little urban influences: parcels were dropped if they were both outside the Core Based Statistical Area counties[7] and more than 10 miles away from the edge of the nearest city (with a population at least 40,000 people). Farmland parcels that were not sold at arm's length[8] were also dropped. These farmland parcel sale records were merged with georeferenced parcel boundaries, or were geocoded based on property addresses using ArcGIS when georeferenced parcel boundaries were not available.[9] In the models, parcels were treated as sold during the pre (boom) period if sold in 2001–2006, and in the post (bust) period if sold in 2009–2010.

Construction of the dependent variable is a common problem in farmland valuation studies, given that sale prices reflect the value of both land and buildings including farm structures, residential dwellings, or both (Nickerson and Zhang 2014). Because we do not have data on the quantity and quality of buildings, we constructed a sales price for farmland only to use as the dependent variable. Similar to Guiling, Brorsen, and Doye (2009), who subtracted the value of buildings from farmland sales prices, we calculated the sales price for farmland only as the original sales price times the ratio of the percentage of *appraised value of land only* over *total appraised value of land and buildings*; 1,343 parcels were dropped

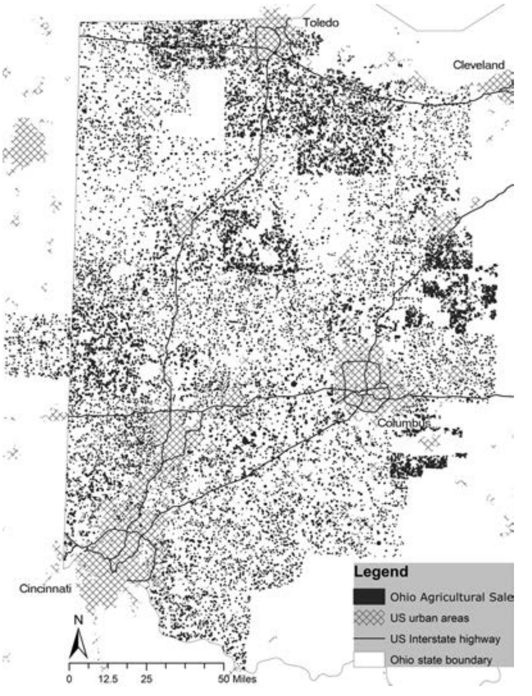

FIGURE 1
Farmland Land Sales Transactions from 2001 to 2010 under Urban Influence in Western Ohio

when the estimated sales price for farmland only was above $20,000/acre or below $1,000/acre. Figure 1 shows a plot of the filtered sample consisting of 12,432 parcel transactions. As is evident from the figure, these data are widely distributed over the entire region. The farmland prices with and without structures are plotted in Figure 2, and the drastic decline experienced in the residential housing markets is not evident. The average nominal farmland sale prices without structures stayed fairly constant around $4,500 per acre over the 2000 decade, varying between 1.2% and 8.5% annually.[10]

Data on parcel attributes and location characteristics were obtained largely from the U.S. Department of Agriculture Natural Resources

[7] Core Based Statistical Areas (CBSAs) are defined by the U.S. Census Bureau as "consist[ing] of the county or counties or equivalent entities associated with at least one core (urbanized area or urban cluster) of at least 10,000 population, plus adjacent counties having a high degree of social and economic integration with the core as measured through commuting ties with the counties associated with the core. The general concept of a CBSA is that of a core area containing a substantial population nucleus, together with adjacent communities having a high degree of economic and social integration with that core" (https://www.census.gov/geo/reference/gtc/gtc_cbsa.htm.).

[8] The sale is deemed arm's length if it contains an arm's-length indicator in the tax assessor's database and the buyer and the seller do not share the same last name.

[9] For these geocoded parcels, the parcel boundaries are proxied by square-shaped parcels with the same acreage.

[10] However, the pace of farmland sales slowed over this period: the number of sales of farmland parcels under urban influence in western Ohio dropped by 50% from an average of 1,513 annually during 2001–2006 to 758 on average during 2009–2010.

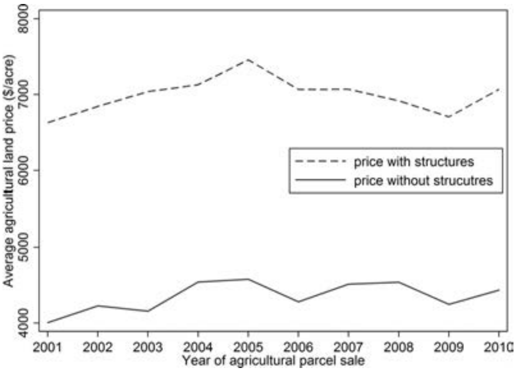

FIGURE 2
Average Arm's-Length Farmland Prices with and without Structures, 2001–2010 in Western Ohio

Conservation Service's GeoSpatial Data Gateway (USDA NRCS 2012), including the Census TIGER/Line Streets, National Elevation Dataset, National Land Cover Dataset, and Soil Survey Spatial Data (SSURGO). Additional data on locations of cities and towns in Ohio were obtained from the Ohio Department of Transportation (2012). We also used Census block shapefiles with 2010 Census population and housing unit counts (U.S. Census TIGER/Line 2012) to calculate the surrounding urban population. Data on ethanol plants, grain elevators, and agricultural terminal ports were obtained from the Ohio Ethanol Council (2012), Farm Net Services (2012), and the Ohio Licensed Grain Handlers list (ODAGWP 2012). Using these data and ArcGIS software (ESRI 2009), we were able to create the parcel attributes and location characteristics. Table 1 reports summary statistics for these variables.

Several variables in Table 1 require explanation. First, the variable National Commodity Crops Productivity Index (NCCPI) measures the potential productivity of the soil, where more desirable soil properties, landscape features, and climatic conditions lead to larger values of NCCPI (for details see Dobos, Sinclair, and Hipple 2008). The *percentage of prime farmland* variable uses SSURGO data and is calculated as the percentage of the parcel's land area that is considered prime for most kinds of field crops. The grain elevators and agricultural terminals were in operation before the start date of this study, and thus the distances to these two types of agricultural delivery points are constant over the study period. However, all of the six ethanol plants in western Ohio did not start operations until 2008. As a result, we assume the positive value of proximity to ethanol plants did not get capitalized before 2007 and thus the variable *distance to nearest ethanol plant* is interacted with a post-2008 time dummy.

Several measures of urban influences are considered: *distance to nearest city center* captures the future rent increases from urban development. *Surrounding urban population within 25 mile radius* also represents nearby demand for future land conversion to urban uses. The *incremental distance to second-nearest city* is a measure commonly used in housing and labor market studies on central place theory and urban hierarchy to capture the additional value of influences from multiple urban centers (e.g., Partridge et al. 2008). The *incremental distance to second-nearest city*, the *surrounding urban population*, and the *gravity index* account for the aggregate urban influences resulting from multiple urban centers. The gravity index is calculated as the weighted average of population divided by distance squared for the nearest three cities, following Shi, Phipps, and Colyer (1997). Together, these four measures capture the most salient aspects of urban influences and are used to construct the urban premium described in equations [7]–[8]. Some additional measures related to urban influences are also considered as controls. The *percentage of building area within a parcel* is included to capture any unobserved value of farm structures and houses that may remain in our "land only" measure of sales price. Because farm houses tend to be old and farm buildings generally do not increase the attractiveness of a parcel for urban residential housing, this variable is excluded in the construction of the urban premium. The *distance to the nearest highway on-ramp* and *the distance to the nearest railway station* represent the additional value of being in close proximity to the interstate network and railway system, respectively. Variables on proximity to road networks are relatively homogenous among parcels and across time in our study region; in

TABLE 1
Summary Statistics of Agricultural Land Sales under Urban Influences in Western Ohio

	Unit	Mean	Std. Dev.	Min.	Max.
General Parcel Attributes					
Sales price per acre (with structures)	Dollars	7,374.65	6,037.55	1,106.2	31,260.4
Sales price per acre (without structures)	Dollars	4,456.96	3,497.43	1,000.16	19,999.71
Log of sales price per acre (without structures)	Dollars	8.16	0.68	6.91	9.90
Assessed land value	Dollars	87,623.20	176,807.40	0	5,878.84
Assessed improvement value	Dollars	32,599.70	59,357.80	0	1,428.25
Assessed land value % of total assessed	%	72.87	29.96	5.38	100.00
Total acres	Acres	46.83	64.68	0.14	2,381
Sale year	Year	2004.96	2.67	2001	2010
Agricultural Profitability Influence Variables					
National Commodity Crops Productivity Index	Number	5,739.35	1,571.55	0	8,800.80
Cropland % of parcel	%	54.49	37.80	0.00	100.00
Prime soil % of parcel	%	37.52	36.18	0.00	100.00
Steep slope ($<$15, 15–25, 25–40, $>$40 degrees)	Multinomial	0.42	0.71	0	3
Distance to nearest ethanol plant	Miles	29.65	13.89	0.55	69.84
Distance to nearest grain elevator	Miles	8.18	6.88	0.03	55.27
Distance to nearest other agricultural terminal[a]	Miles	31.37	14.66	0.13	74.62
Forest area % of parcel	%	16.38	26.84	0.00	100.00
Wetland area % of parcel	%	0.34	2.92	0.00	100.00
Urban Influence Variables					
Distance to nearest city center with over 40,000 people	Miles	22.56	10.57	0.12	57.39
Distance to nearest city center × Post-2008 dummy	Miles	7.36	12.37	0	55.13
Incremental distance to second-nearest city center with at least 40,000 people	Miles	15.10	13.72	0.01	63.59
Incremental distance to second-nearest city center × Post-2008 dummy	Miles	4.68	10.24	0	63.57
Total urban population within 25 miles	Thousands	312.83	236.60	64.77	1,187.38
Total urban population × Post-2008 dummy	Thousands	89.24	176.58	0	1,184.37
Gravity index of three nearest cities		1,326.87	39,204.40	62.14	4,255,332
Gravity index × Post-2008 dummy		674.62	39,194.53	0	4,255,332
Distance to the boundary of urbanized areas with at least 25,000 people	Miles	10.89	7.55	0	33.89
Distance to the boundary of urbanized areas with at least 100,000 people	Miles	19.79	12.51	0	51.91
Building area % of parcel	%	3.32	12.45	0.00	100.00
Distance to highway on-ramp	Miles	3.21	2.05	0	11.94
Distance to railway station	Miles	3.07	1.81	0.01	11.25
Number of observations			12,432		

[a] This measure excludes grain elevators and ethanol plants.

addition, they are shown to have a minor impact compared to the four main urban influence variables described earlier in this paragraph. As a result, these two road network proximity variables are not used to construct the urban premium.

V. RESULTS AND DISCUSSION

Table 2 presents the results of our tests for a structural change in the effect of urban influence using our two approaches: a spatial fixed-effects model with 505 census tract fixed effects, and a spatial error model with a two-nearest-neighbor spatial weights matrix. The key variables are the urban influence variables such as *distance to nearest city center* and their interactions with the post-2008 dummy. The *post-2008 dummy* is defined to be 1 if the parcel is sold after 2008. The interaction terms include the four urban influence variables mentioned in Section III. Com-

TABLE 2
Regression Results with Structural Changes of Urban Influence Variables

	A. Census Tract Fixed-Effects Model		B. Spatial Error Model	
	Coef.	Std. Err.	Coef.	Std. Err.
Intercept	8.0343***	0.1743	8.1000***	0.0646
Assessed land value % of total assessed	0.4270***	0.0226	0.4476***	0.0216
Total acres	− 0.0054***	0.0002	− 0.0056***	0.0001
Total acres squared	2.95E–06***	1.26E–07	3.02E–06***	1.24E–07
Agricultural Profitability Influence Variables				
National Commodity Crops Productivity Index	1.27E–05**	5.16E–06	2.16E–05**	4.86E–06
Prime soil area % of parcel	0.0473**	0.0206	0.0487**	0.0198
Steep slope	− 0.0112	0.0114	0.0035	0.0112
Forest area % of parcel	0.0053	0.0303	0.0485*	0.0294
Wetland area % of parcel	− 0.2851	0.2198	− 0.3232	0.2155
Distance to nearest ethanol plant × Post-2008 dummy	− 0.0023*	0.0014	− 0.0025*	0.0014
Distance to nearest grain elevator	− 0.0011	0.0014	1.29E–05	0.0012
Distance to nearest other agricultural terminal	− 0.0040***	0.0006	− 0.0046***	0.0006
Urban Influence Variables				
Distance to nearest city center × Within 10 miles of urban boundary	− 0.0088***	0.0013	− 0.0096***	0.0012
Distance to nearest city center × Within 10 miles of urban boundary × Post-2008 dummy	0.0051**	0.0026	0.0045**	0.0025
Distance to nearest city center × Beyond 10 miles of urban boundary	− 0.0091***	0.0012	− 0.0083***	0.0011
Distance to nearest city center × Beyond 10 miles of urban boundary × Post-2008 dummy	0.0057***	0.0025	0.0064***	0.0024
Incremental distance to second-nearest city center	− 0.0035***	0.0008	− 0.0044***	0.0007
Incremental distance to second-nearest city center × Post-2008 dummy	0.0027*	0.0016	0.0035**	0.0016
Total surrounding population within 25 miles	2.30E–04***	4.64E–05	2.69E–04***	4.38E–05
Total surrounding population within 25 miles × Post-2008 dummy	9.57E–05	1.20E–04	1.56E–04	1.18E–04
Gravity index of three nearest cities	2.14E–05***	5.68E–06	2.55E–05***	6.02E–06
Gravity index of three nearest cities × Post-2008 dummy	− 2.20E–05***	5.71E–06	− 2.60E–05***	6.05E–06
Building area % of parcel	0.1014**	0.0513	0.1014**	0.0513
Distance to highway on-ramp	− 0.0050	0.0033	− 0.0052	0.0033
Distance to railway station	− 0.0003	0.0036	0.0036	0.0036
Year 2001	− 0.1802	0.1126		
Year 2002	− 0.0880	0.1125	0.1054***	0.0237
Year 2003	− 0.0986	0.1126	0.0972***	0.0233
Year 2004	− 0.0300	0.1124	0.1674***	0.0227
Year 2005	0.0250	0.1126	0.2137***	0.0237
Year 2006	0.0462	0.1126	0.2343***	0.0243
Year 2009	− 0.0406	0.0332	0.1197***	0.1075
Year 2010			0.1462***	0.1109
Spatial autocorrelation coefficient			0.1347***	0.0101
AIC or adjusted R^2	0.2335		19,879	
Root mean squared error	0.6240		0.6264	
Number of observations	10,604		10,378	

Note: The dependent variable in this model is the log of per-acre agricultural land prices without structures. Model A uses the two-nearest-neighbor spatial weights matrix, while Model B uses 505 census tract fixed effects. The Akaike information criterion (AIC) is shown for Model A, while adjusted R^2 is shown for Model B.

*, **, and *** indicate the coefficient is significant at the 10%, 5%, and 1% levels, respectively.

pared to the effects before 2007, the coefficients of these interaction terms indicate the significance and the magnitude of the structural break in the effects of urban influence after the housing market bust. The *distance to nearest city center* is also interacted with dummies for whether the parcel is within or beyond 10 miles from the boundary of an urbanized area with at least 40,000 people.[11] This term allows assessing whether the marginal effect of distance to a city is significantly different for parcels within 10 miles of the boundary of population centers, which previous research suggests is a point beyond which the effect of urban influences on farmland values is much less evident (Nickerson et al. 2012).

Table 2 reveals that the spatial fixed-effects and spatial error models yield qualitatively similar results—the significant decline in the effects of urban influence variables after the housing market bust—and this similarity confirms that this identified structural change is not a spurious effect. The significant spatial fixed-effects and spatial autocorrelation coefficients confirm the presence of spatial dependence. For brevity's sake, we address the results from Table 2's Panel A—the spatial fixed-effects model in the following discussion.

Several points are notable regarding the urban influence variables and their effects. Before 2007, all of the coefficients of the four major urban influence variables are significant at the 1% level, confirming previous findings that urban influence is the most important nonfarm factor shaping farmland values in areas facing urbanization pressures. The biggest of these contributors is the *distance to nearest city center*, whose effect is almost twice as big as that of *incremental distance to second-nearest city center*. The findings indicate that before 2007 surrounding farmland values per acre increased by 0.88% for each one-mile reduction in distance to the nearest city center, which is comparable to the findings of previous studies (e.g., Ma and Swinton 2012). All else equal, the positive benefit per acre resulting from being closer to the nearest city declined from a significant effect of $30.92 per mile before 2007 to an insignificant $12.97 per mile after the housing market bust, an almost 60% reduction. In addition, the effects of multiple urban centers are no longer significant after 2007.[12] In 2009 and 2010, the only urban influence variable that is still significant is the surrounding urban population. One limitation of our data is that the number of observations dropped from 9,079 in 2001–2006 to only 1,517 in 2009–2010, which might play a role in the insignificance in the bust period.

To better understand the magnitude of the structural change, we use the regression results in Table 2 to develop estimates of urban premiums following the methods illustrated in Section III (see Table 3). The four main urban influence variables are included in the construction of the urban premium even if their coefficients are statistically insignificant. From Table 3, we observe that before 2007 relative to the reference parcel not subject to urban influence, the agricultural parcels subject to urban influence on average enjoyed a $1,947 per acre urban premium, or 43% of the per-acre sales price (without structures). However, after 2008, a sizeable reduction in the urban premium occurred: it declined to $1,021 per acre on average, or 23% of the average per-acre sales price. The urban premium estimate for the spatial fixed-effects model is lower than that in the spatial error model. This may be due to the census tract fixed-effects approach underestimating the ur-

[11] The "within 10 miles" binary variable equals one for parcels inside or within 10 miles of the boundary of an urbanized area, and is zero otherwise. The "beyond 10 miles" binary variable equals one for parcels more than 10 miles beyond the boundary of an urbanized area, and is zero otherwise. Results are similar when distances are measured from urbanized areas with 50,000 or 25,000 people instead of 40,000. To account for the greater urban influence of larger cities, we use "within 20 miles" for urbanized areas with at least 100,000 people. These robustness checks are shown in columns (e) and (f) of Appendix Tables A1 and A2.

[12] The significance of the urban influence variables after 2008 is tested using a joint-restriction Wald test. For example, the F-statistic of *incremental distance to second-nearest city center* + *incremental distance to second-nearest city center* × *post-2008 dummy* reveals that the proximity to the second city center is no longer significant at 10% level after 2008.

TABLE 3
Comparison of Urban Premiums (in Dollars) before and after the Housing Market Bust

	Whole Sample		< 10 miles		10–20 miles		30–60 miles	
	Boom	Bust	Boom	Bust	Boom	Bust	Boom	Bust
Panel A: Census Tract Fixed-Effects Model								
Total urban premium	1,947 (1,086)	1,021 (579)	2,993 (1,493)	1,670 (739)	2,258 (1,006)	1,350 (635)	1,158 (465)	669 (281)
1. Miles to nearest city center	1,374 (727)	571 (279)	2,185 (865)	951 (312)	1,631 (600)	741 (252)	721 (322)	351 (140)
2. Incremental distance to second-nearest city center	284 (199)	85 (54)	255 (294)	75 (61)	268 (217)	70 (61)	308 (122)	104 (45)
3. Surrounding urban population	231 (231)	368 (320)	390 (328)	662 (404)	294 (246)	541 (399)	112 (95)	215 (140)
4. Gravity index	59 (93)	2 (39)	165 (183)	17 (133)	66 (66)	2 (2)	17 (12)	1 (1)
Number of observations	9,079	1,517	1,293	128	2,854	406	2,044	478
Panel B: Spatial Error Model								
Total urban premium	2,042 (1,118)	1,106 (791)	3,194 (1,457)	2,034 (852)	2,387 (1,045)	1,554 (895)	1,203 (455)	669 (392)
1. Miles to nearest city center	1,388 (789)	552 (512)	2,316 (866)	1,176 (455)	1,679 (665)	801 (551)	683 (351)	289 (319)
2. Incremental distance to second-nearest city center	339 (220)	94 (56)	290 (325)	80 (65)	317 (240)	79 (65)	376 (133)	113 (42)
3. Surrounding urban population	250 (227)	462 (372)	410 (309)	793 (471)	319 (242)	676 (455)	124 (92)	267 (149)
4. Gravity index	64 (98)	2 (34)	178 (194)	15 (118)	72 (67)	2 (1)	19 (12)	1 (1)
Number of observations	8,890	1,484	1,281	126	2,796	401	2,003	465

Note: The values of *miles to nearest city center*, *incremental distance to second-nearest city*, and *gravity index* after 2008 are included in the calculation of the urban premium, although their corresponding coefficients are not significant at the 10% level. < 10 miles, 10–20 miles, and 30–60 miles are the distance from a farmland parcel to the nearest city center. Standard deviations are in parentheses.

ban premium by absorbing part of the urban effect (Abbott and Klaiber 2011). However, the similar magnitudes across Panels A and B in Table 3 reveal that this potential underestimation is not large.

We also find that, as expected, the urban premium is on average higher for parcels in closer proximity to urban centers. In addition, the housing market bust had a greater impact on parcels closer to urban centers than those farther away, and resulted in some convergence of the size of the urban premium between these two groups. The difference in the estimated size of the urban premium for parcels within 10 miles of the nearest city center was $1,835 greater than that for parcels at least 30 miles away from urban centers before 2007, on average, and this difference shrank to $1,001 after the housing market bust (Table 3).[13]

The stableness of the results is tested using multiple robustness checks shown in Table 4. Different specifications and different samples are used to construct these robustness checks, which largely yield results similar to those of the main specifications in Table 2 (where results differ, we discuss the implications for the urban premium calculations, below). Models I–V test the robustness of the spatial fixed-effects model, while models VI and VII are based on the spatial error model specification. Model I and Model VII includes only the *distance to nearest city center* to investigate the significance and contribution of the other three measures of multiple urban influences in the total urban premium. Model II uses the log of nominal farmland prices, with structures as the dependent variable. Model III uses county fixed effects rather than census tract fixed effects. Model IV tests our assumption of the years 2007–2008 being a transition period by using parcels sold in 2008 as the postperiod group; and Model V assumes the housing market bust happened in 2005 rather than 2007–2008, to examine the possibility of falling urban influence due to factors other than the housing market bust, such as preference changes. Model VI uses four nearest neighbors in the spatial weights matrix. Additional robustness checks for the spatial fixed-effects model, including fixed effects at the census block group or township level, using a log-log specification and other specifications, are included in Appendix Table A1. Spatial error model robustness checks are shown in Appendix Table A3, including the spatial error counterparts for Models II, IV, and V (columns a–c), and different specifications of the spatial weight matrix (columns d–g).

Measures of urban premiums across different specifications shown in Table 5 are fairly robust: both the spatial fixed-effects and spatial error models show that agricultural land parcels experienced, on average, a 40% to 50% decline in urban premium after the housing market bust. In addition, a comparison of Models I and VII in Table 5 with Table 3 reveals that not accounting for the joint effects of proximity to multiple urban centers may significantly underestimate the size of the urban premium, at least in periods of strong housing market growth in regions such as Ohio. Before 2007, excluding the three measures capturing multiple urban center effects would reduce the total urban premium by 16% (from $1,947 to $1,627 per acre, on average) using the spatial fixed-effects results, and by 32% (from $2,042 to $1,394 per acre, on average) using the spatial error model results. The effect of excluding proximity to multiple urban centers is smaller in the bust period and would result in estimates of the urban premium that are 6% and 16% lower in the fixed-effects and spatial error models, respectively.

Several other points are worth noting from the comparison across different specifications shown in Table 5. First, although the urban premium is much higher in Model II, which includes the value of structures in the dependent variable, the urban premium accounts for a similar proportion of price (46%) as models in Table 2, using prices without structures. Second, Model VI and additional robustness checks in Appendix Tables A3 and A4 reveal that the spatial error model results are consistent across different specifications of the spatial weights matrix. Third, the estimate of urban premium using county fixed-effects results (Model III) is 15% higher than the es-

[13] Alternative specifications of urban influences yield similar results. For example, the urban premiums for parcels in MSA counties are about 1.5 times that for parcels in nonmetropolitan counties, on average.

TABLE 4
Robustness Checks across Various Spatial Fixed-Effects and Spatial Error Models

	Spatial Fixed Effects					Spatial Error	
	Model I	Model II	Model III	Model IV	Model V	Model VI	Model VII
Distance to nearest city center × Within 10 miles	− 0.0103***	− 0.0085***	− 0.0119***	− 0.1001***	− 0.0096***	− 0.0104***	− 0.0111***
	(0.0011)	(0.0014)	(0.0018)	(0.0013)	(0.0015)	(0.0013)	(0.0010)
Distance to nearest city center × Within 10 miles × Post-2008 dummy	0.0047**	0.0052*	0.0045**	− 0.0024	0.0004	0.0049*	0.0027
	(0.0022)	(0.0027)	(0.0025)	(0.0029)	(0.0017)	(0.0025)	(0.0022)
Distance to nearest city center × Beyond 10 miles	− 0.0120***	− 0.0089***	− 0.0121***	− 0.0100***	− 0.0098***	− 0.0091***	− 0.0114***
	(0.0008)	(0.0012)	(0.0018)	(0.0012)	(0.0013)	(0.0012)	(0.0008)
Distance to nearest city center × Beyond 10 miles × Post-2008 dummy	0.0053***	0.0060**	0.0051**	− 0.0033	0.0008	0.0063**	0.0045**
	(0.0018)	(0.0026)	(0.0024)	(0.0026)	(0.0016)	(0.0024)	(0.0018)
Incremental distance to second-nearest city center		− 0.0034*	− 0.0072***	− 0.0038***	− 0.0041***	− 0.0046*	
		(0.0008)	(0.0012)	(0.0008)	(0.0009)	(0.0008)	
Incremental distance to second-nearest city center × Post-2008 dummy		0.0033**	0.0022	− 0.0004	− 0.001	0.0031*	
		(0.0008)	(0.0016)	(0.0017)	(0.0011)	(0.0016)	
Urban population within 25 miles		0.0003***	7.55E–06	0.0002***	0.0002***	0.0002***	
		(0.0000)	(0.0001)	(0.0000)	(0.0001)	(0.0000)	
Urban population × Post-2008 dummy		4.19E–05	0.0002	− 0.0004***	− 1.60E–05	0.0002	
		(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	
Gravity index		1.78E–05***	2.06E–05***	1.95E–05***	1.87E–05***	2.41E–05***	
		(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	
Gravity index × Post-2008 dummy		− 1.90E–05***	− 2.10E–05***	− 1.89E–05***	− 1.90E–05***	− 2.47E–05***	
		(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	
Building area % of parcel	0.1266**	0.1386***	0.1009**	0.0657	0.0973**	0.1014**	0.1828***
	(0.0511)	(0.0534)	(0.0500)	(0.0535)	(0.0481)	(0.0513)	(0.0522)
Distance to highway on-ramp	− 0.0071**	− 0.0052	− 0.0042	− 0.0051	− 0.0036	0.0049	− 0.0077**
	(0.0033)	(0.0034)	(0.0032)	(0.0033)	(0.0031)	(0.0035)	(0.0035)
Distance to railway station	0.0018	0.0018	0.0023	0.0005	− 4.42E–06	− 0.0038	0.0019
	(0.0036)	(0.0037)	(0.0035)	(0.0036)	(0.0034)	(0.0036)	(0.0036)
Number of nearest neighbors						4	2
Prices with structures		Yes					
County fixed effects			Yes				
Census tract fixed effects	Yes	Yes		Yes	Yes		
The post period is 2008 only				Yes			
Shifting the year of change to 2005					Yes		
Spatial autocorrelation coefficient						0.0228	0.1541
						− 0.013	− 0.010
Root mean squared error	0.6239	0.6502	0.6169	0.6227	0.6203	0.6219	0.6317
AIC						19,769	20,060
Adjusted R^2	0.2314	0.5033	0.2508	0.2355	0.2197		
Number of observations	10,604	10,604	10,604	10,350	11,723	10,378	10,604

Note: The dependent variable in all models except Model II is the log of per-acre agricultural land prices without structures, and all models use year fixed effects and log-linear specification. The standard errors of the spatial autocorrelation coefficients for these two spatial error models (Models III and IV) are in parentheses. The Akaike information criterion (AIC) is shown for the spatial error model.

*, **, and *** indicate the coefficient is significant at the 10%, 5%, and 1% levels, respectively.

TABLE 5

Predicted Urban Premium (in Dollars) for Table 4's Robustness Checks across Spatial Fixed-Effects and Spatial Error Models

	Spatial Fixed Effects										Spatial Error			
	Model I		Model II		Model III		Model IV		Model V		Model VI		Model VII	
	Boom	Bust	Boom	Bust	Boom	Bust	Boom	Bust	Boom	Bust	Boom	2008	2001–2004	2006–2010
Total urban premium	1,627	959	3,379	1,685	2,273	1,675	2,056	1,899	2,016	1,745	2,105	1,207	1,394	554
	(810)	(420)	(2,292)	(1,513)	(1,111)	(670)	(1,128)	(870)	(1,127)	(728)	(1,158)	(799)	(798)	(514)
1. Miles to nearest city center	1,627	959	2,355	978	1,730	1,079	1,509	1,734	1,430	1,403	1,486	643	1,394	554
	(810)	(420)	(1,601)	(774)	(882)	(871)	(804)	(871)	(765)	(626)	(872)	(557)	(798)	(514)
2. Incremental distance to second-nearest city center			511	5.30	487	447	290	311	309	270	343	156		
			(454)	(4.80)	(332)	(278)	(201)	(205)	(221)	(174)	(221)	(93)		
3. Surrounding urban population			437	710	6.30	151	206	147	227	71	217	411		
			(429)	(802)	(6.20)	(128)	(203)	(129)	(227)	(60)	(194)	(330)		
4. Gravity index			76	8	50	2	51	1.25	49	0.24	59	2		
			(105)	(164)	(81)	(31)	(81)	(37)	(81)	(9)	(91)	(36)		
Number of nearest neighbors									4	2				
Prices with structures			Yes											
County fixed effects					Yes									
Census tract fixed effects	Yes	Yes			Yes									
The post period is 2008 only							Yes							
Shifting the year of change to 2005									Yes					
Spatial autocorrelation coefficient									0.0228	0.1541				
									(0.013)	(0.010)				
Root mean squared error	0.6239	0.6502	0.6169	0.6227	0.6203	0.6219	0.6317							
Adjusted R^2	0.2314	0.5033	0.2508	0.2355	0.2197									
Number of observations	9,086	1,477	9,086	1,513	9,083	1,517	9,079	1,262	6,271	5,445	8,892	1,484	8,892	1,484

Note: The estimated standard errors of the spatial autocorrelation coefficients are in parentheses.

timate based on the census tract fixed-effects model. This may arise from differences in the magnitude of the coefficient on the *distance to nearest city center,* which is 30% higher in the county fixed-effects model (Table 4, Model III) than that in the census tract fixed-effects model (see Table 2, Panel A). This higher estimate could result from omitted characteristics at the subcounty level; however, it may also be due to an underestimation of the total urban effect by our census tract fixed-effects model.[14] Fourth, Model IV reveals no significant decline in urban influence in the year 2008 compared to 2001–2006, validating our assumption that there is a time lag before the housing market bust starting from early 2007 transmitted into related surrounding farmland markets. Finally, Model V reveals that there is no significant change in the effects of the most important influence variable, the *distance to nearest urban center*, if we assume the housing market bust happened in 2005. This supports the notion that there were no fundamental demand concerns other than the housing market bust in 2007 that could result in a downward trend in urban influences on farmland values since 2001.

The standard hedonic price method assumes linear parameterization and fixed functional form, which may introduce bias when the functional form for explanatory variables is not correct. To address this potential misspecification bias, we ran two additional robustness checks. The first adopts a log-log specification rather than the log-linear form used in all previous regressions, and the results for the fixed-effects model are shown in column (d) in Appendix Tables A1 and A2. The second involves propensity score matching, which does not assume a particular functional form for the price function (Heckman and Navarro-Lozano 2004). To implement matching, we constructed treatment and control groups based on distances to nearest city center and ran several difference-in-difference regressions and regular regressions on the matched sample using different matching algorithms and different definitions of proximity to urban centers.[15] Although the magnitude of urban premium is not the same, these two robustness checks both yield qualitatively similar conclusions as the main specifications that the value of being close to urban areas significantly declined due to the recent housing market bust.

VI. CONCLUSION

Farm real estate is a significant source of value in the farm sector balance sheet and in the typical farm household investment portfolio. Because changes in farm real estate values have significant implications for farm sector health and farm household well-being, understanding the key determinants of changes in U.S. farmland prices is of perennial interest to policymakers. With nearly one-quarter of U.S. farmland estimated to be subject to urban influences, the effects of changes in demand for residential housing markets on farmland values are of particular interest—especially in light of the significant housing market bust in 2007–2008 in which housing values fell by 40% in major metropolitan areas. To our knowledge our study provides the first empirical evidence that farmland values near urbanizing areas were not immune to the effects of the urban housing market bust. Farmland values were more greatly affected in our study area than the modest decline suggested by simple trend analysis.

Using a hedonic modeling approach and farmland parcel sales data in western Ohio, this paper estimates the magnitude of the value of proximity to urban areas (the "urban premium") to have declined from more than 40% to about 20% of farmland values shortly after the residential housing market bust. The

[14] Additional robustness checks using census block group fixed effects or township fixed effects yield similar results as the main census tract fixed-effect specification shown in Table 2. These results are shown in columns (a) and (b) of Appendix Tables A1 and A2. We note that the former model shows a lower estimate of the decline in urban premium, which suggests that when defined at spatial scales lower than census tract, the fixed-effects model may capture even more of the effects of distance.

[15] We thank the reviewers for pointing out the rationale for using matching to control for misspecification problems. The results on matching and related regressions are available from the authors upon request.

two main model specifications, a spatial fixed-effects model and a spatial error model, yield similar results, suggesting that the unobserved characteristics giving rise to spatial correlation are adequately controlled by either approach. Our results also demonstrated that not accounting for proximity to multiple urban centers can underestimate the value of the urban premium by 16% to 32%, at least in periods of strong residential housing market growth and in regions like Ohio. Furthermore, a variety of robustness checks, including the use of propensity score matching, yield similar conclusions that the effects of urban proximity declined substantially in 2009–2010.

Despite the decline in the significance and magnitude of the urban premium after 2008, farmland prices remained relatively steady over our study period—a trend that has been noted in other parts of the United States (Nickerson et al. 2012). Increased commodity demands over this period appear to have contributed to the stability of farmland prices in western Ohio; the significant effect of proximity to an ethanol plant after 2008, for example, indicates that proximity to new commodity buyers may have substantially obscured the impact on farmland values of the downturn in the urban residential housing market. These findings suggest that farmland values—and, hence, farm sector and farm household wealth—would have increased substantially after 2006 had the housing bust not occurred. Our findings of a significant decline in the impacts of urban influences in 2009 and 2010 are short-run effects and do not necessarily suggest urban influences are much less important for surrounding farmland parcel values in the long run.

APPENDIX

TABLE A1
Additional Robustness Checks for Spatial Fixed-Effects Model

	(a)	(b)	(c)	(d)	(e)	(f)
Distance to nearest city center × Within 10 miles	− 0.0096***	− 0.0092***	− 0.0094***	− 0.1300***	− 0.0095***	
	(0.0015)	(0.0012)	(0.0013)	(0.0229)	(0.0013)	
Distance to nearest city center × Within 10 miles × Post-2008 dummy	0.0038	0.0051**	0.0050***	0.0991**	0.0048*	
	(0.0027)	(0.0026)	(0.0016)	(0.0492)	(0.0026)	
Distance to nearest city center × Beyond 10 miles	− 0.0102***	− 0.0081***	− 0.0087***	− 0.1370***	− 0.0090***	
	(0.0013)	(0.0011)	(0.0011)	(0.0218)	(0.0012)	
Distance to nearest city center × Beyond 10 miles × Post-2008 dummy	0.0049*	0.0051**	0.0070***	0.1111**	0.0060**	
	(0.0026)	(0.0026)	(0.0011)	(0.0472)	(0.0025)	
Distance to nearest city center						− 0.0091***
						(0.0012)
Distance to nearest city center × Post-2008 dummy						0.0055**
						(0.0024)
Incremental distance to second-nearest city center	− 0.0037***	− 0.0038***	− 0.0053***	− 0.0252***	− 0.0036*	− 0.0035*
	(0.0008)	(0.0007)	(0.0007)	(0.0068)	(0.0008)	(0.0008)
Incremental distance to second-nearest city center × Post-2008 dummy	0.0016	0.0038**	0.0082***	0.0123	0.0024	0.0027*
	(0.0017)	(0.0017)	(0.0012)	(0.0159)	(0.0016)	(0.0016)
Urban population within 25 miles	0.0002***	0.0003***	0.0002***	0.0003***	0.0002***	0.0002***
	(0.0001)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Urban population within 25 miles × Post-2008 dummy	7.99E–05	0.0001	0.0002**	9.82E–05	0.0001	8.23E–05
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Gravity index	1.85E–05***	2.62E–05***	2.2E–05***	1.15E–05*	2.09E–05***	2.12E–05***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Gravity index × Post-2008 dummy	− 1.90E–05***	− 2.70E–05***	− 2.3E–05***	− 1.20E–05*	− 2.10E–05***	− 2.20E–05***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Building area % of parcel	0.0793	0.0961*	0.1112**	0.0592	0.1001*	0.1015**
	(0.0534)	(0.0518)	(0.0511)	(0.0523)	(0.0513)	(0.0512)
Distance to highway on-ramp	− 0.0021	− 0.0045	− 0.0019	− 0.0129***	− 0.0055*	− 0.0051*
	(0.0034)	(0.0033)	(0.0032)	(0.0050)	(0.0033)	(0.0033)

(table continued on following page)

TABLE A1
Additional Robustness Checks for Spatial Fixed-Effects Model *(continued)*

	(a)	(b)	(c)	(d)	(e)	(f)
Distance to railway station	− 0.0008	− 0.0045	− 0.0045	0.0006	0.0005	0.0004
	(0.0038)	(0.0036)	(0.0036)	(0.0086)	(0.0036)	(0.0036)
Year fixed effects	Yes	Yes		Yes	Yes	Yes
Price deflator using quarterly Housing Price Index			Yes			
Functional form	Log-linear	Log-linear	Log-linear	Log-log	Log-linear	Log-linear
Spatial fixed effects	Census block group	Township	Census tract	Census tract	Census tract	Census tract
Root mean squared error	0.6170	0.6301	0.6200	0.6244	0.6239	0.6239
Adjusted R^2	0.2505	0.2216	0.2432	0.2324	0.2336	0.2336
Number of observations	10,604	10,604	10,817	10,604	10,604	10,604

Note: Column (c) uses the quarterly Housing Price Index from the Federal Housing Finance Agency, following suggestions from one reviewer, while the other specifications use just year fixed effects without a price deflator. In column (e) we change *within 10 miles of the boundary of urbanized areas with at least 50,000 people* to *within 20 miles of the boundary of urbanized areas with at least 100,000 people* to account for the greater urban influence of larger cities. In all models the dependent variable is the log of per-acre agricultural land prices without structures. The estimated standard errors of the spatial autocorrelation coefficients are in parentheses.

*, **, and *** indicate the coefficient is significant at the 10%, 5%, and 1% levels, respectively.

TABLE A2
Predicted Urban Premium (in Dollars) across Additional Robustness Checks Shown in Table A1

	(a)		(b)		(c)		(d)		(e)		(f)	
	Boom	Bust	Boom	Bust	Boom	Bust	Boom	Bust	Boom	Bust	Boom	Bust
Total urban premium	1,927	1,363	1,985	906	1,931	680	1,261	718	1,993	1,136	1,829	826
	(1,177)	(743)	(1,089)	(637)	(1,073)	(698)	(948)	(539)	(1,127)	(693)	(1,028)	(456)
1. Miles to nearest city center	1,404	874	1,355	489	1,301	492	689	139	1,417	633	1,296	465
	(849)	(471)	(721)	(330)	(720)	(360)	(516)	(100)	(770)	(367)	(694)	(219)
2. Incremental distance to second-nearest city center	292	216	304	5	376	324	158	96	282	119	262	73
	(217)	(148)	(206)	(3)	(264)	(200)	(156)	(88)	(197)	(75)	(184)	(46)
3. Surrounding urban population	182	275	256	424	203	515	374	487	238	387	218	290
	(189)	(250)	(239)	(353)	(198)	(402)	(377)	(427)	(234)	(327)	(217)	(253)
4. Gravity index	50	1	70	2	52	3	40	3	56	2	54	2
	(81)	(21)	(107)	(30)	(82)	(41)	(64)	(51)	(87)	(36)	(85)	(32)
Number of observations	9,071	1,517	8,902	1,476	9,190	1,621	9,082	1,517	9,078	1,517	9,079	1,517

Note: Standard deviations are in parentheses.

TABLE A3
Additional Robustness Checks for the Spatial Error Model

	(a)	(b)	(c)	(d)	(e)	(f)	(g)
Distance to nearest city center × Within 10 miles	− 0.0086***	− 0.0103***	− 0.0094***	− 0.0096***	− 0.0099***	− 0.0093***	− 0.0106***
	(0.0013)	(0.0012)	(0.0013)	(0.0012)	(0.0013)	(0.0012)	(0.0014)
Distance to nearest city center × Within 10 miles × Post-2008 dummy	0.0046*	0.0022	0.0003	0.0045*	0.0048*	0.0046*	0.0052**
	(0.0026)	(0.0027)	(0.0027)	(0.0025)	(0.0025)	(0.0025)	(0.0025)
Distance to nearest city center × Beyond 10 miles	− 0.0076***	− 0.0083***	− 0.0073***	− 0.0083***	− 0.0086***	− 0.0080***	− 0.0096***
	(0.0012)	(0.0011)	(0.0012)	(0.0011)	(0.0012)	(0.0011)	(0.0013)
Distance to nearest city center × Beyond 10 miles × Post-2008 dummy	0.0067***	0.0028	0.0002	0.0064***	0.0063***	0.0064***	0.0066***
	(0.0025)	(0.0024)	(0.0015)	(0.0024)	(0.0024)	(0.0024)	(0.0024)
Incremental distance to second-nearest city center	− 0.0036***	− 0.0043***	− 0.0044***	− 0.0044***	− 0.0045***	− 0.0042***	− 0.0049***
	(0.0007)	(0.0007)	(0.0008)	(0.0007)	(0.0007)	(0.0007)	(0.0008)

(table continued on following page)

TABLE A3
Additional Robustness Checks for the Spatial Error Model *(continued)*

	(a)	(b)	(c)	(d)	(e)	(f)	(g)
Incremental distance to second-nearest city center × Post-2008 dummy	0.0038** (0.0017)	0.0010 (0.0016)	0.0004 (0.0010)	0.0035** (0.0016)	0.0034** (0.0016)	0.0036** (0.0016)	0.0030* (0.0016)
Urban population within 25 miles	0.0003*** (0.0000)	0.0003*** (0.0000)	0.0003*** (0.0000)	0.0003*** (0.0000)	0.0003*** (0.0000)	0.0003*** (0.0000)	0.0002*** (0.0000)
Urban population within 25 miles × Post-2008 dummy	1.00E–04 (0.0001)	− 3.64E–04*** (0.0001)	− 1.54E–04** (0.0001)	1.56E–04 (0.0001)	1.58E–04 (0.0001)	1.33E–04 (0.0001)	1.60E–04 (0.0001)
Gravity index	2.08E–05*** (0.0000)	2.29E–05*** (0.0000)	2.56E–05*** (0.0000)	2.55E–05*** (0.0000)	2.47E–05*** (0.0000)	2.54E–05*** (0.0000)	2.43E–05*** (0.0000)
Gravity index × Post-2008 dummy	− 2.14E–05*** (0.0000)	− 2.28E–05*** (0.0000)	− 2.55E–05*** (0.0000)	− 2.61E–05*** (0.0000)	− 2.50E–05*** (0.0000)	− 2.60E–05*** (0.0000)	− 2.50E–05*** (0.0000)
Building area % of parcel	0.1790*** (0.0542)	0.0307 (0.0540)	0.0402 (0.0498)	0.1511** (0.0521)	0.1437*** (0.0520)	0.1534*** (0.0521)	0.1498*** (0.0517)
Distance to highway on-ramp	− 0.0063* (0.0035)	− 0.0076** (0.0033)	− 0.0069** (0.0031)	− 0.0052 (0.0034)	− 0.0054 (0.0035)	− 0.0056 (0.0033)	− 0.0044 (0.0036)
Distance to railway station	0.0053 (0.0036)	0.0021 (0.0034)	0.0004 (0.0032)	0.0036 (0.0036)	0.0039 (0.0036)	0.0043 (0.0035)	0.0039 (0.0036)
Prices with assessed building values	Yes						
The post period is 2008 only		Yes					
Shifting the year of change to 2005			Yes				
Spatial weights matrix	2nn	2nn	2nn	Scalar-normalized	Inverse-distance	1nn	4nn
Spatial autocorrelation coefficient	0.1255*** (0.0102)	0.1459*** (0.0105)	0.1454*** (0.0099)	0.0673*** (0.0051)	0.1814*** (0.0118)	0.0844*** (0.0077)	0.2827*** (0.0148)
AIC	20,692	17,035	19,189	19,878	19,821	19,931	19,711
Root mean squared error	0.6517	0.5849	0.5836	0.6264	0.6240	0.6287	0.6197
Number of observations	10,378	10,378	10,378	10,378	10,378	10,378	10,378

Note: In all models the dependent variable is the log of per-acre agricultural land prices without structures, except for column (a). In column (d), we use a scalar-normalized spatial weights matrix instead of a row-standardized one, following the suggestions of Kelejian and Prucha (2010), in which the scalar is the minimum of the maximum row sums and maximum column sums of the input weights. In column (e), we use an inverse-distance spatial weights matrix rather than a *k*-nearest-neighbor one. 1nn, 2nn, and 6nn denote a 1-nearest-neighbor, 2-nearest-neighbor, and 6-nearest-neighbor spatial weights matrix, respectively. The estimated standard errors of the spatial autocorrelation coefficients are in parentheses. AIC, Akaike information criterion.

*, **, and *** indicate the coefficient is significant at the 10%, 5%, and 1% levels, respectively.

TABLE A4
Predicted Urban Premium (in Dollars) across Additional Robustness Checks Shown in Table A3

	(a)		(b)		(c)		(d)		(e)		(f)		(g)	
	Boom	Bust	Boom	Bust	Boom	Bust	Boom	Bust	Boom	Bust	Boom	Bust	Boom	Bust
Total urban premium	3,345	1,587	1,925	2,012	1,805	1,654	2,042	1,106	2,065	1,131	2,012	1,029	2,138	1,236
	(2,273)	(1,776)	(1,115)	(963)	(1,066)	(775)	(1,118)	(791)	(1,139)	(830)	(1,102)	(766)	(1,176)	(813)
1. Miles to nearest city center	2,208	709	1,334	1,385	1,207	1,197	1,388	552	1,425	568	1,348	506	1,529	653
	(1,558)	(1,065)	(809)	(736)	(746)	(654)	(789)	(512)	(830)	(532)	(750)	(478)	(910)	(582)
2. Incremental distance to second-nearest city center	546	65	300	339	307	324	339	94	339	114	327	59	357	189
	(484)	(59)	(202)	(219)	(208)	(204)	(220)	(56)	(219)	(69)	(213)	(36)	(230)	(113)
3. Surrounding urban population	505	950	239	232	242	133	251	462	238	450	272	466	193	397
	(478)	(1,009)	(221)	(170)	(238)	(103)	(227)	(372)	(215)	(363)	(247)	(375)	(173)	(319)
4. Gravity index	87	8	52	56	49	1	64	2	62	2	65	2	59	3
	(121)	(154)	(82)	(143)	(89)	(18)	(98)	(34)	(95)	(37)	(101)	(36)	(89)	(39)
Number of observations	8,890	1,484	8,890	1,484	8,890	1,484	8,890	1,484	8,890	1,484	8,891	1,484	8,890	1,484

Note: Standard deviations are in parentheses.

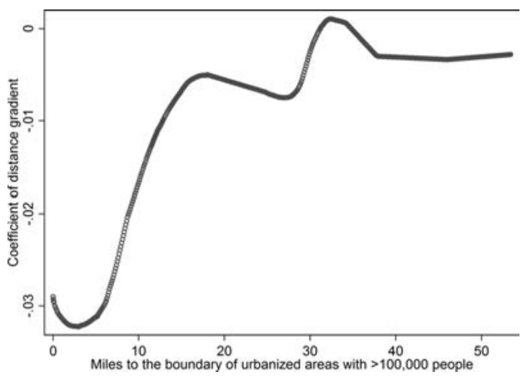

FIGURE A1
Semiparametric Analysis: Miles to the Boundary of Urbanized Areas with at Least 100,000 People

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